TECHNICAL NOTES

U.S. Department of Agriculture
Natural Resources Conservation Service
Columbus, Ohio

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LANDSLIDES

Landslides occur in all parts of Ohio and are caused by a variety of factors. Size of slipped areas varies from a few square feet up to many acres. Requests for assistance on this type of problem requires that NRCS field personnel have a basic knowledge of landslide processes in order to evaluate landslide prone areas.

Ohio may have the highest per-capita cost for landslide damages within the United States. A study showed that between 1973 and 1978 the annual per-capita cost for Hamilton County residents was $5.80, while that of Los Angeles was $1.60. A recent slip on Mt. Adams in Cincinnati cost $25 million for repairs. Landslide damages are costly.

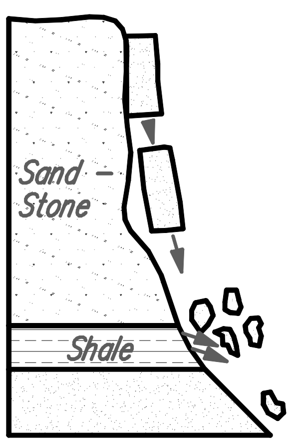
DEFINITION: Landslides are rapid mass movements of soil and rock moving downhill under the influence of gravity. Although landslides are a process of erosion, they are quite different from sheet erosion and "creep". Creep is the slow downhill movement of soil masses and may be responsible for tilted or out of line fence posts and poles along roadbanks. Landslides are characterized by actual failures (breaks) in the soil or rock structure, with the broken part carried downhill.

The term "soil" in this report is used in an engineering geology sense, i.e., all unconsolidated material overlying bedrock. Where the term is used in an agronomic sense, the specific soil type will be named.

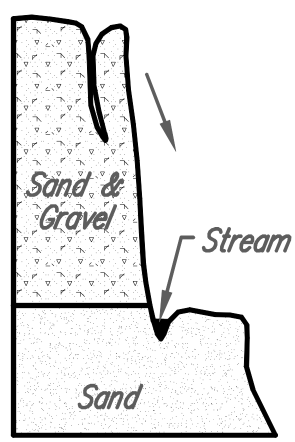
CLASSIFICATION: Landslides are classified according to the type of movement and the materials involved. There are three major divisions in the classification system, with numerous subdivisions. Only the subdivisions commonly seen in Ohio will be discussed in this paper. Classification is the first step for analysis and solution of the problem.

Types of landslides are:

1. Falls – Landslides where the moving mass travels downward through the air under free-fall. They occur as rockfalls; although, they can occur in soil along streambanks. Movement of failed material is very rapid. Rockfalls are aided by extension of joints (cracks within a rock).

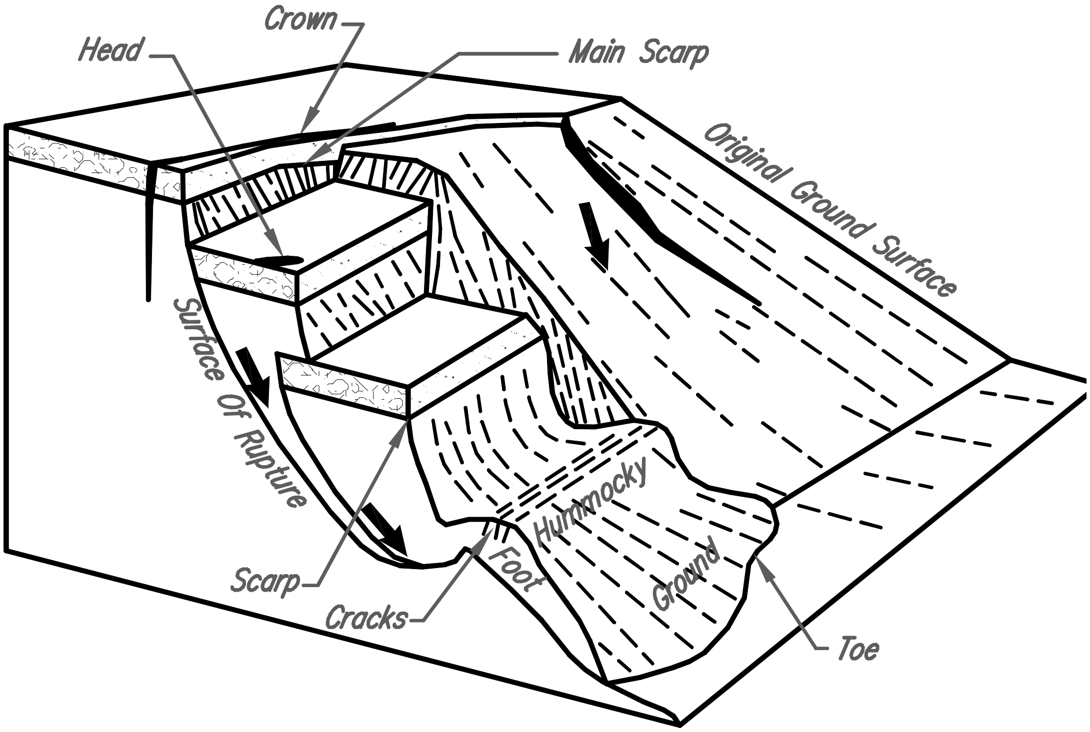


ROCKFALL



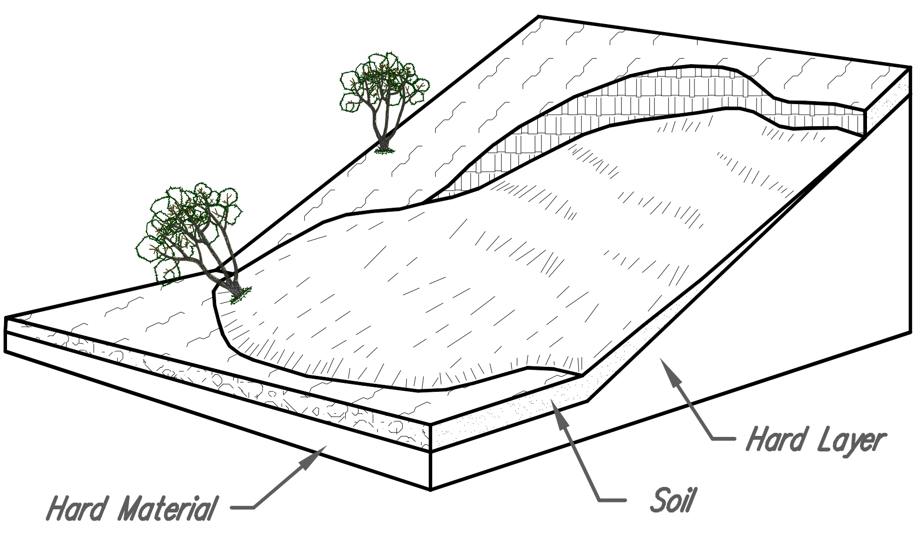
SOILFALL

2. Slides – Landslides where the movement results from shear failure along one or several surfaces. The most common type of slide in Ohio is the rotational slump. In this kind of slide, the surface of failure is somewhat circular, with movement that is rotational about an axis that is parallel to the slope. The depth to the failure surface is dependent upon the geology of the site. The area of the slide is frequently spoon shaped in extent. The head may be tilted down in an upslope direction; the toe is commonly bulged upward and hummocky. Cracks may be present. Rotational slumps may begin on a slope with subsequent slides "migrating" up the slope. Water that is ponded at the head of the scrap can cause repeated slippage.



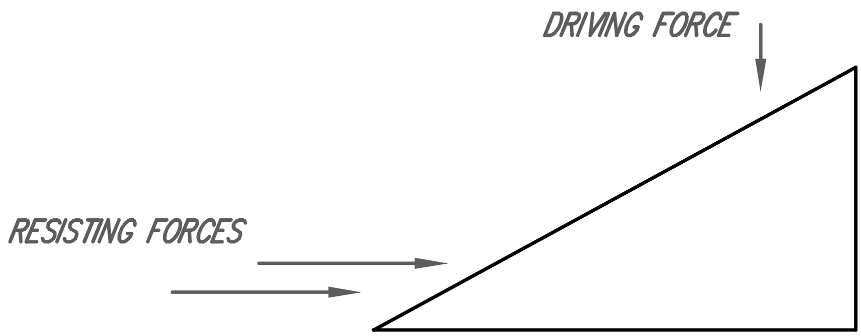
ROTATIONAL SLUMP

3. Flows – Landslides where the movement of the material resembles the flow of viscous fluid downward along a surface of failure. Flows are generally thin.



EARTHFLOW

CAUSES: On all slopes there are two kinds of forces, the driving force and the resisting force. The driving force pushes the soil downhill under the influence of gravity. The force consists of the total weight of moist or saturated soil, plus buildings, trees, etc. The resisting forces act against the driving force and are internal properties of the soil or artificial measures constructed by man. Examples of resisting forces include shear strength (higher in sands and gravels than in silts) and cohesion (mainly in clays). Artificial measures include retaining walls and embankments at the base of slopes.



On stable slopes, the resisting forces are stronger than the driving forces. On unstable slopes the reverse is true. Within any specific area, both kinds of forces may change in magnitude because of various factors. Landslides are rarely caused by a single factor. Slides generally occur in an area that is generally slightly on the plus side to equilibrium, and what is commonly thought of as the "cause" is really the factor that gives the slide its "push". Various reasons for landslides are as follows:

Factors that contribute to increased stress:

1. Removal of (lateral) horizontal support at the base of a slope due to erosion by streams or the action of man.

2. Loading of a surface by buildings or manmade fill.

3. Creation of a steeper slope angle, by man or nature.

4. Uplift pressure within the soil or rock due to water or pressure due to formation of ice in cold weather. Pressure from ice formation is particularly effective in splitting sandstone along joints (cracks within rock).

Internal factors that contribute to low strength:

1. The initial composition of the soil; some soils are weaker than others.

2. Arrangement of individual particles within the soil. A loose particle arrangement in silts forms a soil known as "quickclays". These are highly sensitive and will fail when saturated if subject to a shock.

3. Geological position of the soil. Soil and rock layers or joints that are inclined towards a cut or valley are more susceptible to sliding than those inclined away from a cut or valley. Strata of weak, highly plastic soils within the soil mass may be susceptible to sliding.

4. Changes due to weathering such as physical disintegration or removal of cement within the rock.

5. Chemical changes that weaken the soil or rock such as hydration of clays.

6. Drying of clay soils with resultant cracking can promote future rapid saturation of the soil mass by rainfall.

7. Buoyancy of saturated soils due to the excessive amount of water. In this case, known as high pore pressures, the water supports part of the load on the soil. Water does not support a load as well as the solid part of the soil. Moisture conditions are extremely important and may be the only ones we can recognize with any degree of certainty without extensive testing. Moisture conditions may change rapidly due to the seasons and weather.

PREDICTIONS OF LANDSLIDES: Analysis of the various causes of landslides has shown that the problem is complex. It is difficult to predict if a specific site will slide. Visual observations of a wide broad area will show it is landslide prone, and information thus obtained can then be applied to a specific site. For design purposes, at a specific site, it may also be necessary to gather subsurface data in addition to the surficial observations.

In many areas, there are indications that landslides have occurred in the past. These surface features are:

1. Hummocky ground is one of the easiest clues to recognize. Old slip form irregular ripples on slopes or surfaces that may even tilt backwards into the slope.

2. Steep Bare scarps always form at the head of a rotational slump. The scarp will eventually be obliterated by erosion.

3. Tilted trees can indicate past slope movement if the trunk bends upslope or downslope.

4. Fences tilted in a downslope direction may indicate an old slide. Fences will be offset downslope across a slide area.

5. Water plays an important part in causing landslides. Water may be seen seeping out of the ground at the scarp or toe of a slide.

6. Published soil surveys identify soils known to have a high probability of slippage. These soils are delineated on the detailed soil maps in each published soil survey report. Soils having slip potential are also named later in the geologic (and geographic) section of this note.

EVIDENCE OF IMPENDING SLIDES:

1. Cracks will appear in the soil during initial soil movement. They can be parallel to and/or perpendicular to the slope.

2. A sudden slight lowering of land surface downslope from a crack may indicate that a larger movement may be imminent.

3. Trees and fences suddenly start to lean downhill.

4. Seepage of water is not by itself a clue of an impending slide, but it is evidence to be used along with other clues.

PREVENTING THE PROBLEM: It is best for land-use planners to consider landslide hazards and to identify slide prone areas. Every effort should be made to avoid disturbances of sites where landslides have or may occur. If landslide prone areas must undergo development, there are several factors to keep in mind.

1. Avoid steepening or disturbing of steep slopes even though they appear to be stable.

2. Water from surface runoff roofs, leach beds, etc., should be carried downslope without entering the soil and effecting its stability. Blind drains should be eliminated, as well as depressions that pond water. Exposures of highly permeable soil that act as infiltration traps should be dealt with.

3. Avoid placing fills on steep slopes, and avoid construction on these fills.

4. Avoid removal of the toe of slopes.

5. The effects of trees on areas of potential landslides are complex. Research done by Mary Riestenberg of the University of Cincinnati indicates that tree roots "increased the factor of safety against sliding nine-fold." Root strength allows forested, colluvium-mantled hillsides in the Cincinnati area to resist sliding at slope angles as high as 35^o, whereas similar slopes devoid of trees are subject to sliding at slope angles of 12^o to 14^o. The contribution of tree roots to slope stability should be evaluated before removal of trees for development of hillsides. "The major -difficulty involved in a study of the contribution of roots to soil strength is that their distribution is patchy and difficult to predict…the estimation of root strength for computation of factors of safety is a major problem." Tree roots add to soil strength only if the roots penetrate below a potential surface of rupture, but roots have no effect on stabilizing a potential landslide that has a deep surface of rupture. Tree roots can stabilize soil in the immediate vicinity of a tree, but may have little effect when trees are dormant, and most slips in Ohio occur during the late fall to early spring. Removal of trees may contribute to slope instability due to root decay, which can leave open holes within soil allowing for easy penetration by water.

Structural measures for landslide prevention such as internal drainage, retraining walls, piers, etc., are beyond the scope of this technical note. All structural measures should be designed and constructed under the supervision of a professional engineer who is experienced in soil and rock stability problems.

<u>CORRECTING LANDSLIDES</u>: Landslides are complex problems, and treatment requires careful investigation by trained geologists and engineers. Each case is different from others, and each requires its own particular corrective measures. There is no one set formula that will apply to the repair of all landslides. Proper treatment will be concerned with the slipped area as a whole and not be limited to just part of it. An important point to remember is that a broken soil surface is always a surface of weakness. Hillsides can slip, remain at rest for years, and then slip again. Any landslide having the surface of rupture within bedrock is much more difficult to correct than one where the surface of rupture is wholly within the soil.

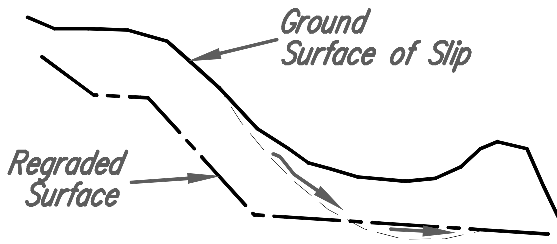
Remedial work may involve the still-stable soil upslope from the slipped area, as well as the slipped material. Planting trees or placing shallow retaining walls are generally useless. Trees add weight to slopes, and their roots do not rapidly absorb large volumes of excessive water. Proper corrective measures are generally very expensive, (can cost more than the property is worth) and there is never a guarantee that a particular measure will provide permanent protection. In some situations, the only practical treatment involves removal of the slipped material. It should be noted that this might increase the instability and encourage further landslides. In spite-of this lack of surety, there are several measures that have produced success in many landslide areas. Some of these measures are:

1. Regarding the slope to a flatter one. It can be achieved by cutting down the top of the hill or regrading the entire hill from bottom to top.

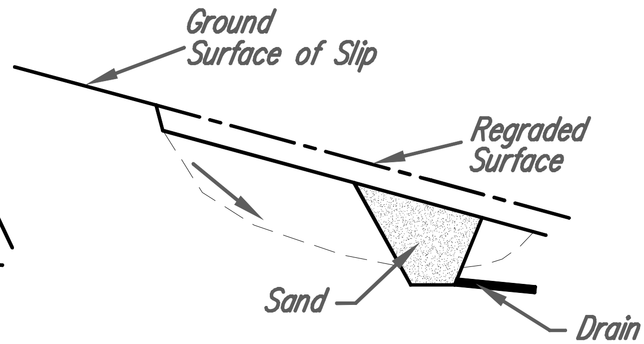
2. Installation of drainage systems to remove water. This is very important. Reduced moisture content reduces the chance of reoccurring landslides.

3. Installation of pilings and retaining walls. Structural measures such as these must be driven into the still-stable foundation below the plane of slippage and deep enough to resist being overturned by future movement. They are constructed of wood, steel, or concrete and are costly. Effective installation requires proper design and emplacement by a qualified expert.

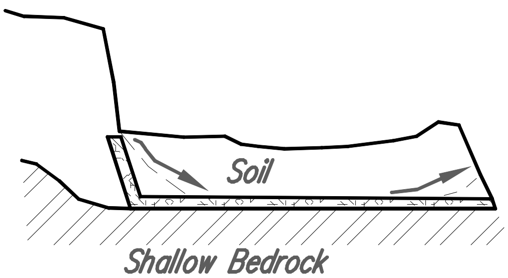
All corrective measures should be designed and constructed under the supervision of a professional engineer who is experienced in soil and rock stability problems. In all cases, the design should be based on a detailed subsurface investigation.



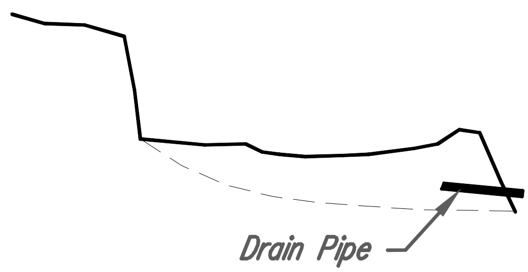
REMOVAL OF SLIPPED
MATERIAL AND REGRADING



INSTALLATION OF SHEAR-
RESISTANT MATERIAL



INSTALLATION OF
GRAVEL DRAIN



INSTALLATION OF PLASTIC DRAINPIPE
BY MEANS OF SPECIAL EQUIPMENT

RELATIONSHIP OF OHIO'S GEOLOGY TO LANDSLIDES: Although landslides occur throughout Ohio, there are wide geographic areas where the basic geology affects landslides within that particular portion of the state.

Southeast Ohio:

Many landslides in southeast Ohio are associated with bedrock or the soils derived from them. About 75% of the slides occur within 20% of the stratigraphic rock sequence, predominantly in those parts characterized by the thickest red shales and claystones. The troublesome red shales are found in the upper part of Monongahela Group and are scattered through the underlying Conemaugh Group.

These slides of red shales take the form of rotational slumps with the curved plane of failure passing through the bedrock. In some cases, the movement assumes major proportions. Two noteworthy slides involving red shales are the one, which occurred during construction on I-77 near Dexter City, and the one at Monticello apartments in Athens. One theory ascribes the failure of these shales to a deficiency of the element potassium within the shale, which allows for water to be attached to the clay particles. A rough field test to check shale stability is to immerse a lump in water and note how rapidly slaking occurs. In one case, pieces of red (and green) shale disintegrated within 10 seconds. Such rocks should be considered landslide prone upon coming in contact with water.

Smaller landslides occur within soils of the CH type, which result from the weathering of the red shales. Vandalia and Brookside soils on slopes, and the Guernsey and Upshur soils are known for slippages.

Rockfalls of sandstone bedrock have occurred at Pomeroy and at Old Man's Cave in the Hocking Hills. Both falls were probably triggered by ice expansion within vertical jointing.

Northeast Ohio:

The area northeast of Akron and east of Cleveland has landslides that are affected by the glacial geology. The glacial deposits consist of tills that are separated by lacustrine silts and clays. The lacustrine materials can be unstable. Examination of soil survey maps will delineate Geeburg and Brecksville soils, which have developed upon lacustrine materials. Water moving through the horizontally laminated lacustrine soils develop high pore pressure. Slipped lacustrine materials, which underlie till can cause rotational slumping of the till. The slips are particularly susceptible to streambank erosion. They can also slip if manmade cuts relieve support at the toe of a slope. Tests run on soils near the village of Peninsula indicate that the silts have a lower strength and higher natural water content than the till. Landslides within till have also occurred because of steeping of slopes or drainage changes by man during construction.

Southwest Ohio:

The landslides in the Cincinnati area are related to two geological factors:

1. Colluvium overlying bedrock.

2. Soils due to the effects of glaciation.

The bedrock is apparently stable. The landslide problems take place within colluvial soils that overlie the Kope Formation and Miamitown Shale. Both rock types are shales and are relatively impermeable to water movement. Thick colluvium containing an excessive flow of water is susceptible to rotational slumps; thin colluvium can slip by rapid earthflow. Soils which develop from the colluvium are mapped in soil surveys as Pate and Eden, and are classified in these reports as being susceptible to sliding.

Landslides are common in early spring when the ground is saturated from winter snow and rain. Studies of landslides within the Kope Formation indicate that most of them were triggered by Man's activities. The Mt. Adams slide referred to in the beginning of this note was caused when a trench was excavated at the toe of the slope. Ninety-two percent of these slides were on north-facing slopes, which are probably wetter than the south-facing slopes due to less direct sunshine. Slopes over 15% should be considered to have high potential for stability problems.

Landslides have not been observed in natural slopes of glacial till but have been common in manmade cuts and fills. These slides are typical rotational slumps. Slope angles of 13 areas prior to failure ranged from 42 to 78 percent. The failures are probably caused by inadequate drainage within the till.

Lacustrine and terrace silts and clay within this region are due to blocked stream drainage by the glaciers. These soils are "patchy" in a real extent due to the area's complex glacial history. These soils can be recognized by their horizontal laminated structure. They are weaker than the till, and slopes underlain by them are susceptible to landslides.

<u>REFERENCES</u>:

There are several textbooks on landslides, as well as chapters in various soil mechanics texts. One good book on the subject written in a rather direct manner is:

Landslides Analysis and Control
Special Report 176
Transportation Research Board
National Academy of Sciences

Other useful publications, which are specifically limited to a geographical area of Ohio, are:

A Symposium on Landslides
Proceedings of the Ohio University Research Institute
Athens, Ohio Department of Natural Resources
February 26, 1969

Engineering and Pleistocene Geology of the Lower Cuyahoga River Valley
George Gardener, Arthur H. Wittine, et als.
Selected Field Trips in Northwestern Ohio
Guidebook No. 2
Ohio Division of Geological Survey

Slope Stability and Landslides
Proceeding of the 6th Ohio Valley Soils Seminar,
Sponsored by Cincinnati Geotechnical Group ASCE and University of Cincinnati Department of Civil and Environmental Engineering

Engineering Geology of the Cincinnati Area
Robert W. Fleming, Arvid M. Johnson, and Manes E. Hough
Field Trip No. 18
Geological Society of America
Cincinnati 1981 Meetings

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